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P-23

Ultrafast imaging of the phononic response of split-ring-resonator

［1］Organization

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［2］Research Progress

High acoustic-frequency experiments were carried out with tunable excitation (pump) optical pulses to locally excite the picosecond acoustic waves, and delayed independently-tunable probe optical pulses for excitation and detection of surface motion or refractive index changes. This system is shown in Fig. 1

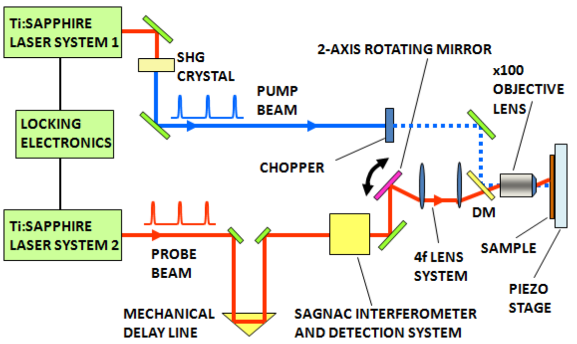

Fig. 1: Schematic diagram of the laser system used for experiments on GHz excitation and detection of vibrations of acoustic metamaterials.

This system was put to use to excite GHz vibrations in arrays of split ring resonators, an electromagnetic metamaterial.

We have also made use of acoustic and optical simulation packages for surface acoustic waves: PzFlex and COMSOL Multiphysics.

［3］Results

（3－1）Research results We have fabricated and carried out experiments on a gold split-ring resonator (SRR) array of thickness 60 nm as shown by the design and SEM (scanning electron micrograph) of Fig. 2.

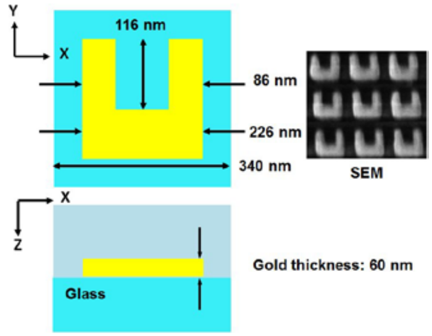

Fig. 2: Schematic diagram of the fabricated SRR unit cell structure together with a SEM micrograph.

This structure is designed to show an optical resonance in the near infrared, at a wavelength ~800 nm accessible with our femtosecond laser system. Simulations with COMSOL for the electromagnetic response gives reasonable agreement with the experimentally measured transmission spectrum of the sample in the near-infrared to visible region .

Results for the relative reflectivity change in the time domain for normal incidence with pumping at wavelength 400 nm and probing at wavelength 800 nm are Fourier transformed to reveal the vibrational resonant response of the SRRs. Results for different pump and probe polarizations are shown in Fig. 3.

We observe a much stronger response when the probe is polarized in the X direction (see Fig. 8), as expected because this probe polarization couples strongly to the electromagnetic modes of the SRR.

In order to interpret the observed vibrational resonances below ~10 GHz, we carried out simulations with both COMSOL and PZFlex.

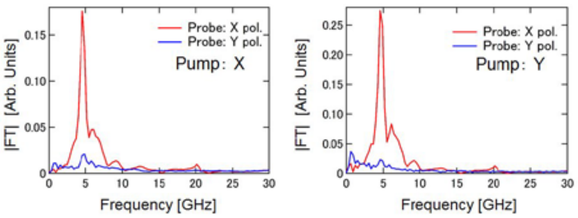

Fig. 3: Modulus of the temporal Fourier transform of the reflectance change variation for pumping and probing a nanoscale gold SRR array at different linear polarizations. Structural vibrations of the SRR are evident up to ~10 GHz.

We find reasonable agreement with experiment for the position of the vibrational modes, as shown in Fig. 4, but with different amplitudes, as expected because the details of the plasmonic interactions with the sample were not taken account of in the simulations. The frequency resolution of the COMSOL simulations is better because of the longer time taken for the simulation.

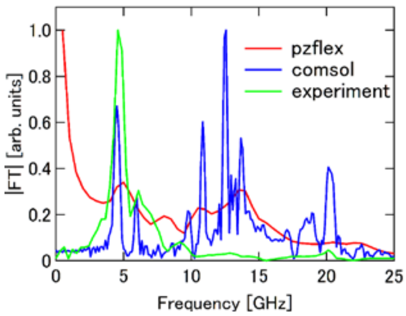

Fig. 4: Comparison of the frequency spectrum in experiment (Pump Y and Probe X) and in simulations with COMSOL and PzFlex, showing broad agreement of the acoustic resonance positions but with different amplitudes. The simulation shows the longitudinal strain along the z axis on the SRR surface.

(3－2) Ripple effects and further developments

Applications of this work include high frequency acousto-optic modulators. This work is being prepared for submission to the journal Applied Physics Letters. Related papers in this field were also published (see achievements list).

In future we wish to extend the results to a variety of probe optical wavelengths to investigate the effect of the plasmonic resonance on the acoustic response. Moreover, we wish to extend this research to plasmonic nanolenses in collaboration with Shizuoka University.

［4］Achievements (List of Publications)

（1）'Optical tracking of picosecond coherent phonon pulse focusing inside a sub-micron object'
T. Dehoux, K. Ishikawa, P. H. Otsuka, M. Tomoda, O. Matsuda, M. Fujiwara, S. Takeuchi, I. A. Veres, V. E. Gusev and O. B. Wright
Light Sci. Appl. 5, 16082 (2016)

（2）'On the origin of negative density and modulus in acoustic metamaterials'
S. H. Lee and O. B. Wright
Phys. Rev. B 93, 024302 (2016)

Travelling Report（Mention each travel by CRP budget.）

Name：Oliver B. Wright
Affiliation：Hokkaido University
Period of time：August 3-August 6, 2015
Period of time：March 2-March 5, 2016
Destination：Shizuoka University
Purpose：Research discussions and experiments
Name of receiver：Oliver B. Wright